



What does Business Intelligence have to do with Interplanetary Spacecraft Communications?

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Presentation Overview

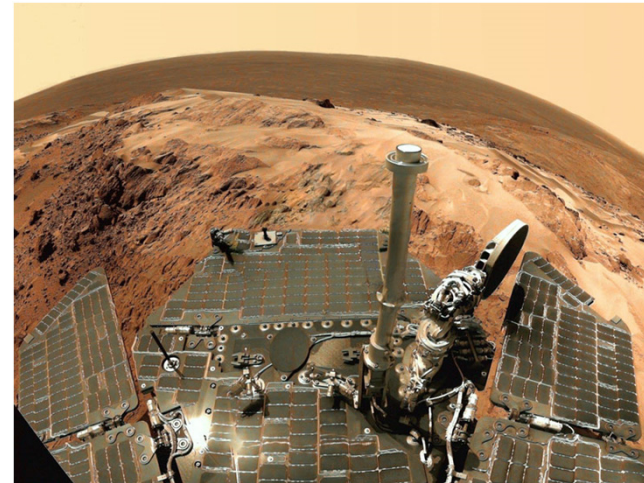
- Who are and what do we do?
- The Deep Space Network (DSN)
- Applying BI to the DSN
- Lessons, Observations along the way so far



Who Are We + What Do We Do?

JPL is the primary NASA center for spacecraft exploring the Solar System and Beyond

From very early rocket research in 1936...



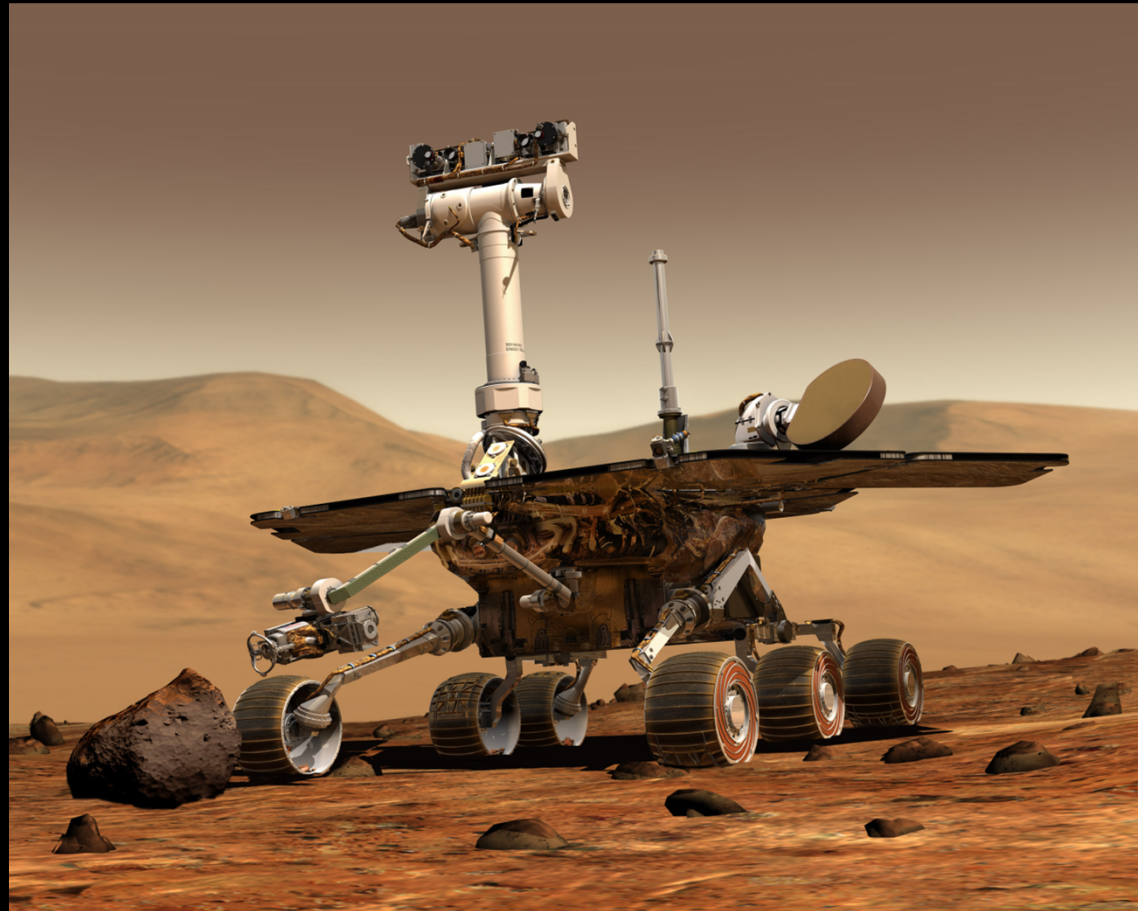
...to solar system exploration on Mars and beyond

~5500 Scientists, Engineers, Operations personnel

Lets take a look at some examples...

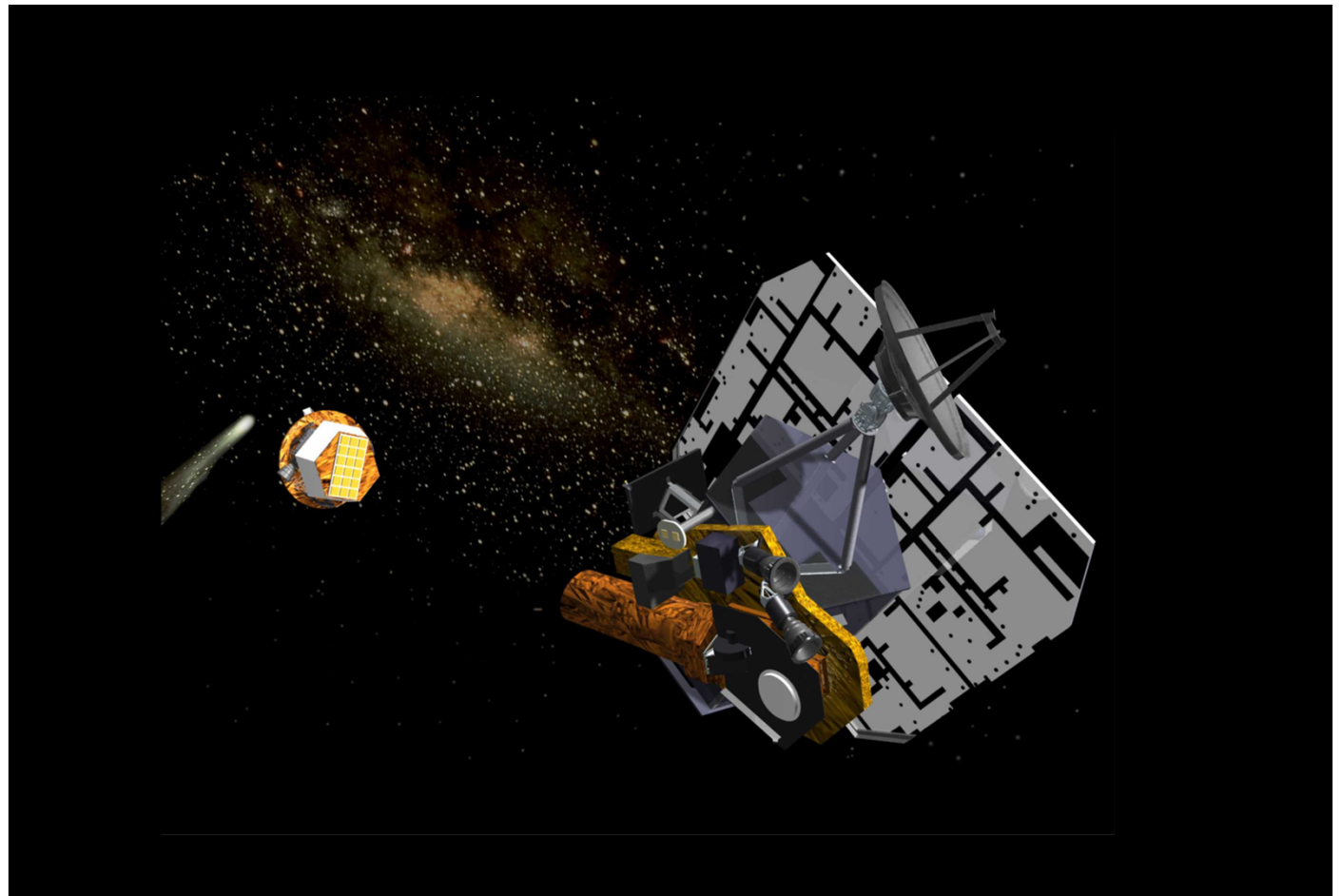
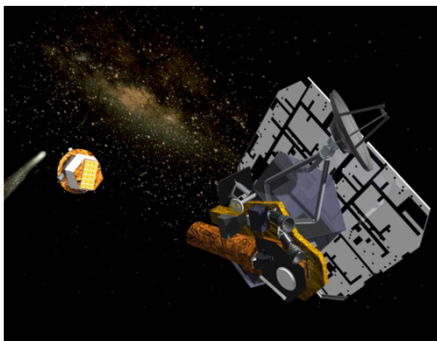


We Explore Mars...





...We Investigate Comets...





...We Engineer Serious Enabling Infrastructure



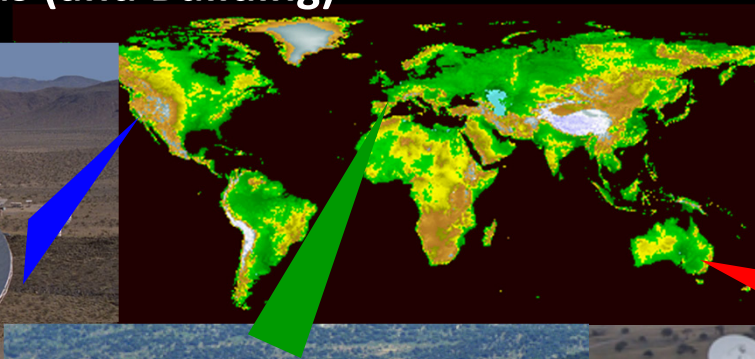


Deep Space Network Overview

- Three major tracking sites around the globe provide continuous communications and navigation support for the world's deep space missions
- 15 Deep Space Antennas (and Building)



Goldstone
California



Madrid
Spain

Canberra
Australia

- Formally established in 1963
- Services include telemetry, command, ranging, radio science
- Supports ~ 40 missions including planetary orbiters, landers (Mars), earth orbiters
- Service Production => ~10,000 – 15,000 data points/sec, 24x7



Deep Space/Solar System Communication Domain

- DSN is at the limit of current human telecommunications achievement:
 - Voyager 1:
 - Communication Distances in excess of 17 Billion Kilometers (> 31 hrs round trip light time)
 - 20 Watt transmitter
 - Incident energy at DSN antenna is $5.0e-11$ that of a typical digital watch battery (20 billion times less energy)



- Large, custom-built antennas, variety of different types
- High power transmitters – lots of safety interlocks
- Feeble signals sensitive to weather issues, low elevation angles
- Wide range of data rates – 10 bits/sec – to 6 Mbps (and climbing)



So Lets Apply Some Bl....



Applying BI to DSN Network Operations

- BI => OI (Operations Intelligence)
- Inventory => Assets
- ROI measured in terms of operations efficiency, higher levels of service, lower operating costs
- Sales => service hours and science data returned
- Orders => service requests
- Regions => network complex centers
- Stores => antennas
- Products => Data frames, packets and files



Current User Profiles

- Systems and Operations Engineers
 - Minimize Discrepancy and Anomaly Reports
 - Root-Cause Analysis
 - Detailed Data
 - Subsystem Domain Specific Knowledge
- Complex and Network Management
 - Reduce Operations and Maintenance Costs
 - Increase Levels of Service
 - Increase Levels of Automation
 - Efficient Asset Maintenance
 - Increase Equipment Availability



Our Typical BI Workflow So Far...

- Automated ETL at predefined intervals
- Automated report generation and distribution via e-mail
- Management Reports delivered in “ready” formats via MicroStrategy Office and PowerPoint templates
- Interactive analysis triggered by “red” metrics in periodic reports



Types of Questions...



DSN + BI
Application
Overview So Far...



Service Levels, Equipment Utilization

Deep Space Network (DSN)
DSN Weekly Data
Delivery Performance
Week 52, 2010



1-Week Summary

Schedule Week			2010-52		
			Telemetry %	Command %	Radio Metric %
Mission					
ACE	ACE	92	98.1%	96.5%	94.3%
CAS	Cassini	82	100.0%	100.0%	100.0%
CHDR	CHANDRA	151	100.0%	99.5%	100.0%
CLU1	Cluster 1	183	100.0%		
CLU2	Cluster 2	185	100.0%		
CLU3	Cluster 3	194	100.0%		
CLU4	Cluster 4	196	100.0%		
DAWN	DAWN	203	100.0%	100.0%	100.0%
GTL	Geotail	1	100.0%		
KEPL	Kepler	227	97.9%	100.0%	97.9%
M010	Odyssey	53	99.8%	100.0%	99.3%
MER1	MER1	253	100.0%	100.0%	100.0%
MER2	MER2	254	100.0%	100.0%	100.0%
MEX	MEX	41	100.0%	100.0%	100.0%
MRO	MRO	74	99.6%	98.7%	98.3%
MSGR	Messenger	236	99.6%	99.2%	98.2%
NHPC	New Horizons	98	98.4%	100.0%	100.0%
ROSE	Rosetta	226	100.0%	100.0%	100.0%
SDU	SDU	29	94.9%	94.5%	94.6%
SOHO	Soho	21	99.7%	99.2%	100.0%
STA	STA	234	99.6%	100.0%	99.7%
STB	STB	235	99.3%	100.0%	100.0%
STF	SIRTF	79	98.7%	100.0%	100.0%
THB	THEMIS B	192	100.0%	78.0%	78.5%
THC	THEMIS C	193	100.0%	100.0%	100.0%
VGR1	VOYAGER 1	31	99.5%	100.0%	
VGR2	VOYAGER 2	32	99.8%	100.0%	
WIND	Wind	8	100.0%	100.0%	100.0%
Total			99.3%	98.6%	98.2%

Notes:

4-Week Summary

Mission			Telemetry %	Command %	Radio Metric %
ACE	ACE	92	99.5%	95.6%	95.4%
CAS	Cassini	82	99.8%	99.9%	98.7%
CHDR	CHANDRA	151	98.7%	98.8%	99.7%
CLU1	Cluster 1	183	99.5%		
CLU2	Cluster 2	185	100.0%		
CLU3	Cluster 3	194	99.5%		
CLU4	Cluster 4	196	98.8%		
DAWN	DAWN	203	98.9%	100.0%	99.9%
DIF	Deep Impact	140	100.0%	100.0%	100.0%
GTL	Geotail	1	99.8%		
INTG	INTEGRAL	198	98.8%	98.5%	98.4%
KEPL	Kepler	227	99.5%	100.0%	99.4%
LRO	LRO	85	100.0%	100.0%	100.0%
M010	Odyssey	53	99.3%	99.3%	95.7%
MER1	MER1	253	100.0%	95.4%	99.4%
MER2	MER2	254	100.0%	100.0%	100.0%
MEX	MEX	41	99.8%	100.0%	95.8%
MRO	MRO	74	99.5%	99.6%	99.4%
MSGR	Messenger	236	99.1%	99.7%	98.2%
NHPC	New Horizons	98	99.6%	100.0%	100.0%
PLC	PLANET C	5	100.0%	100.0%	100.0%
ROSE	Rosetta	226	100.0%	100.0%	100.0%
SDU	SDU	29	98.1%	98.5%	97.0%
SOHO	Soho	21	99.9%	98.9%	100.0%
STA	STA	234	99.9%	99.1%	98.9%
STB	STB	235	99.8%	99.7%	99.5%
STF	SIRTF	79	99.6%	100.0%	100.0%
THB	THEMIS B	192	100.0%	94.3%	94.3%
THC	THEMIS C	193	100.0%	100.0%	100.0%
VGR1	VOYAGER 1	31	96.2%	100.0%	
VGR2	VOYAGER 2	32	99.9%	100.0%	
WIND	Wind	8	100.0%	100.0%	100.0%
Total			99.3%	99.2%	98.6%

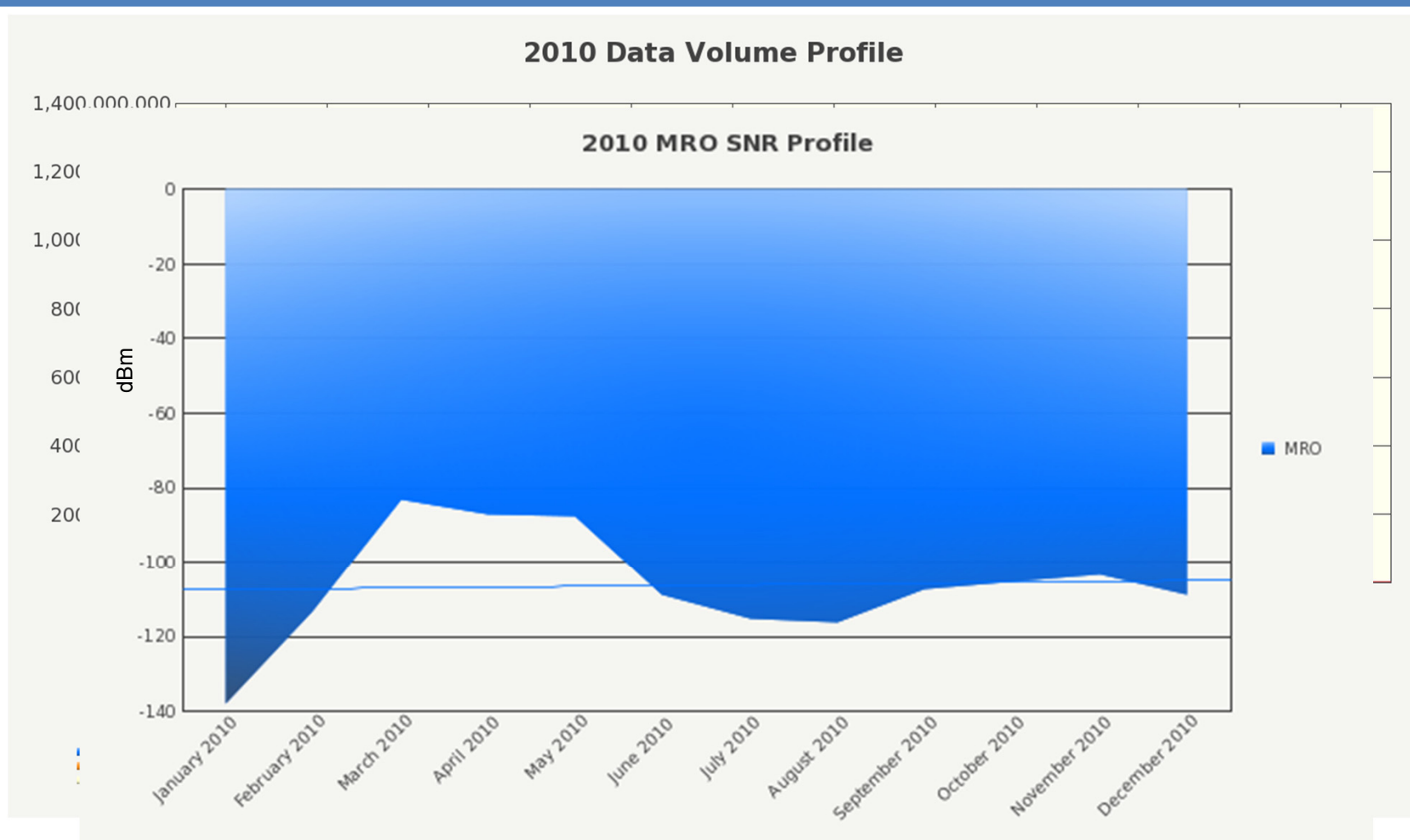
Antenna Utilization - Downlink

- December 2010 -

		Mission Use										Planned Other Activities										Unplanned Activities (Corrective Maint)				Time Not Scheduled			
		X-Band					S-Band					K-Band					Maintenance												
		Single Spacecraft		Multiple Spacecraft			Single Spacecraft		Multiple Spacecraft			Single Spacecraft		Multiple Spacecraft			Preventive		Corrective										
DSCC Location	Antenna & Aperture	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%				
GOLDSTONE	14	239	32%	50	7%	56	8%	0	0%	8	1%	0	0%	30	4%	64	9%	216	29%	57	8%	27	4%						
	15	251	34%	39	5%	79	11%	0	0%	0	0%	0	0%	48	6%	40	5%	273	37%	0	0%	14	2%						
	24	171	23%	29	4%	261	35%	0	0%	0	0%	0	0%	31	4%	40	5%	185	25%	0	0%	18	2%						
	25	217	30%	6	1%	N/A	0%	N/A	0%	12	2%	0	0%	31	4%	40	5%	398	55%	0	0%	37	5%						
	26	208	28%	92	12%	N/A	1%	N/A	0%	0	0%	0	0%	30	4%	40	5%	342	46%	0	0%	25	3%						
	27	N/A	0%	N/A	0%	385	52%	0	0%	0	0%	0	0%	35	5%	40	5%	103	14%	0	0%	181	24%						
CANBERRA	34	118	16%	125	17%	277	37%	0	0%	21	3%	0	0%	28	4%	0	0%	129	18%	0	0%	61	8%						
	43	320	43%	224	30%	29	4%	0	0%	5	1%	0	0%	43	6%	0	0%	62	8%	0	0%	65	9%						
MADRID	45	238	32%	76	10%	227	30%	0	0%	0	0%	0	0%	39	5%	0	0%	136	18%	0	0%	35	5%						
	54	141	19%	30	4%	266	36%	0	0%	9	1%	0	0%	38	5%	0	0%	22	3%	0	0%	249	33%						
	55	270	36%	100	14%	N/A	0%	N/A	0%	25	3%	0	0%	34	5%	0	0%	27	4%	0	0%	310	42%						
	63	276	37%	71	9%	15	2%	0	0%	19	2%	0	0%	63	8%	0	0%	32	4%	0	0%	289	39%						
	65	193	26%	42	6%	219	29%	0	0%	0	0%	0	0%	24	3%	0	0%	25	3%	0	0%	248	33%						

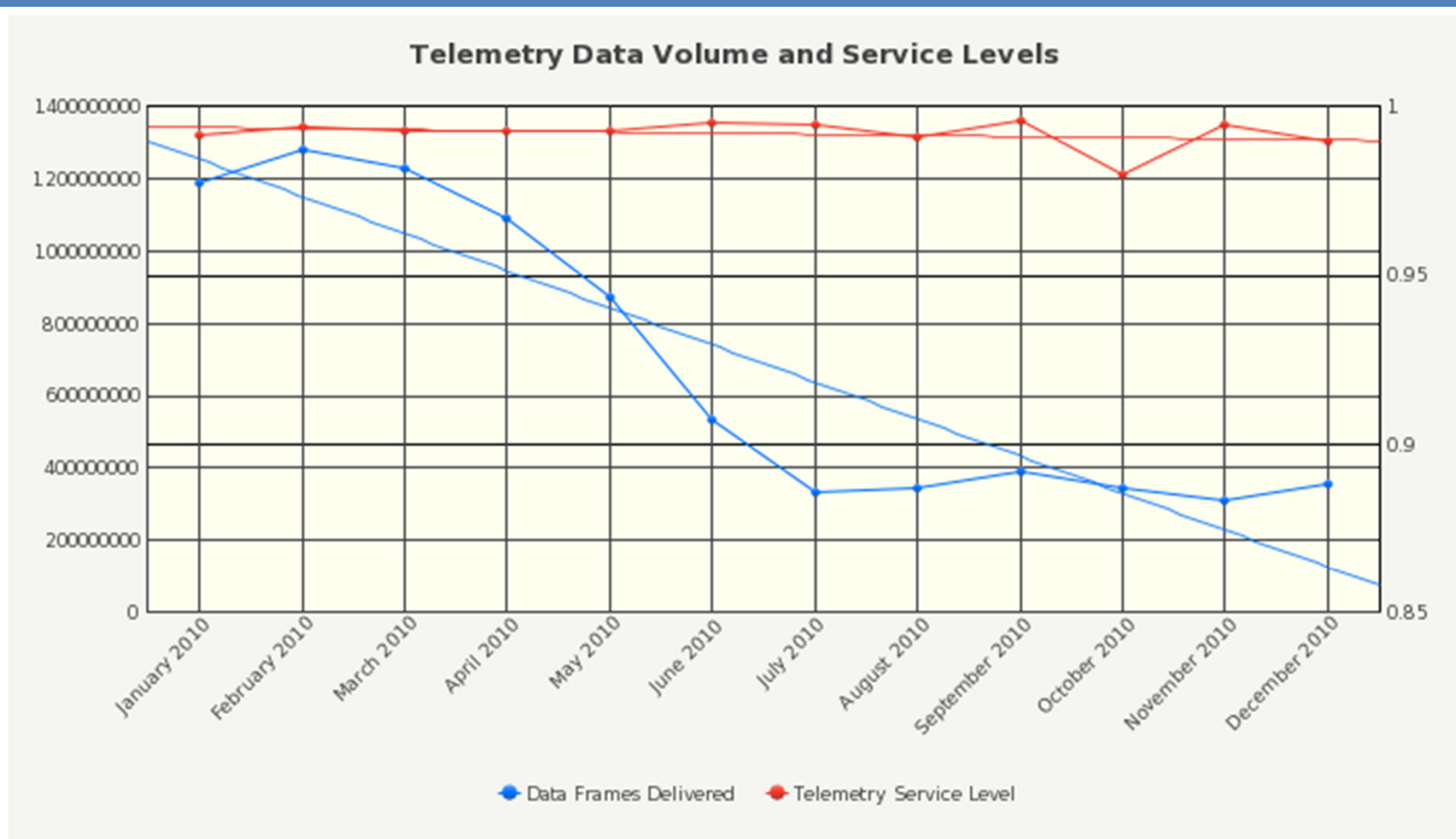


Solar System Mission Communication Volume Profile 2010





Service Volume vs. Quality





Week:
Mission
DSCC
Subsystem
Assembly
Cause

(ALL)

(ALL)

(ALL)

(ALL)

(ALL)

MRO

GOLDSTONE

DTT

RRP9

Software

TLP5

Software

NMC

NMC-SR1

Unknown

DCC9

Software

RRP8

Weather

ANT34BWG

SRDC

Hardware

Software

CANBERRA

DTT

TLP5

Procedural 2

RRP5

Software

N/A

N/A

Project

MADRID

DTT

RRP2

Software

RRP1

Software

ANT34BWG

ASI

Hardware

M010

GOLDSTONE

ANT34BWG

SRDC

Hardware

Software

CANBERRA

ANT34BWG

ASI

Hardware

N/A

N/A

Low Elevation

MADRID

SOHO

GOLDSTONE

ANT

WSA

Unknown

ETX

BVE

Hardware

NHPC

GOLDSTONE

N/A

N/A

Dependency

ANT

APM

Software

MADRID

DTT

TLP8

Weather

CANBERRA

ANT70

ANT

Hardware

ACE

GOLDSTONE

ANT

WSA

Unknown

NMC

NMC-SR1

Unknown

ETX

BVE

Hardware

MER2

MADRID

UPL

UEC

Procedural 2

UPA1

Procedural 1

ETX

BVE

Procedural 2

VGR1

GOLDSTONE

DTT

DCC7

Software

RRP1

Weather

VGR2

CANBERRA

N/A

N/A

Weather

DTT

TLP4

Weather

STB

GOLDSTONE

UPL

URA

Software

MADRID

DTT

TLP8

Software

CHDR

GOLDSTONE

ETX

BVE

Hardware

MADRID

DTT

RRP2

Unknown

CAS

GOLDSTONE

ANT

APM

Software

ANT70

AC2

STF

GOLDSTONE

DP5

PDG

Maintenance Related Failure

STA

MADRID

DTT

TLP4

Weather

M5GR

GOLDSTONE

N/A

N/A

Weather

MEX

GOLDSTONE

ANT

APM

Software

GTL

GOLDSTONE

DTT

KEPL

MADRID

UWV

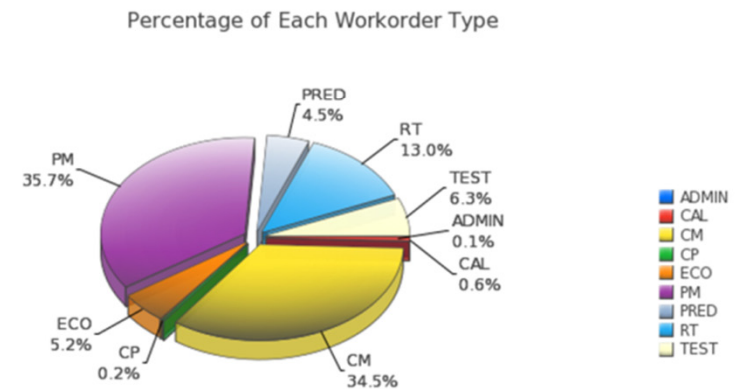
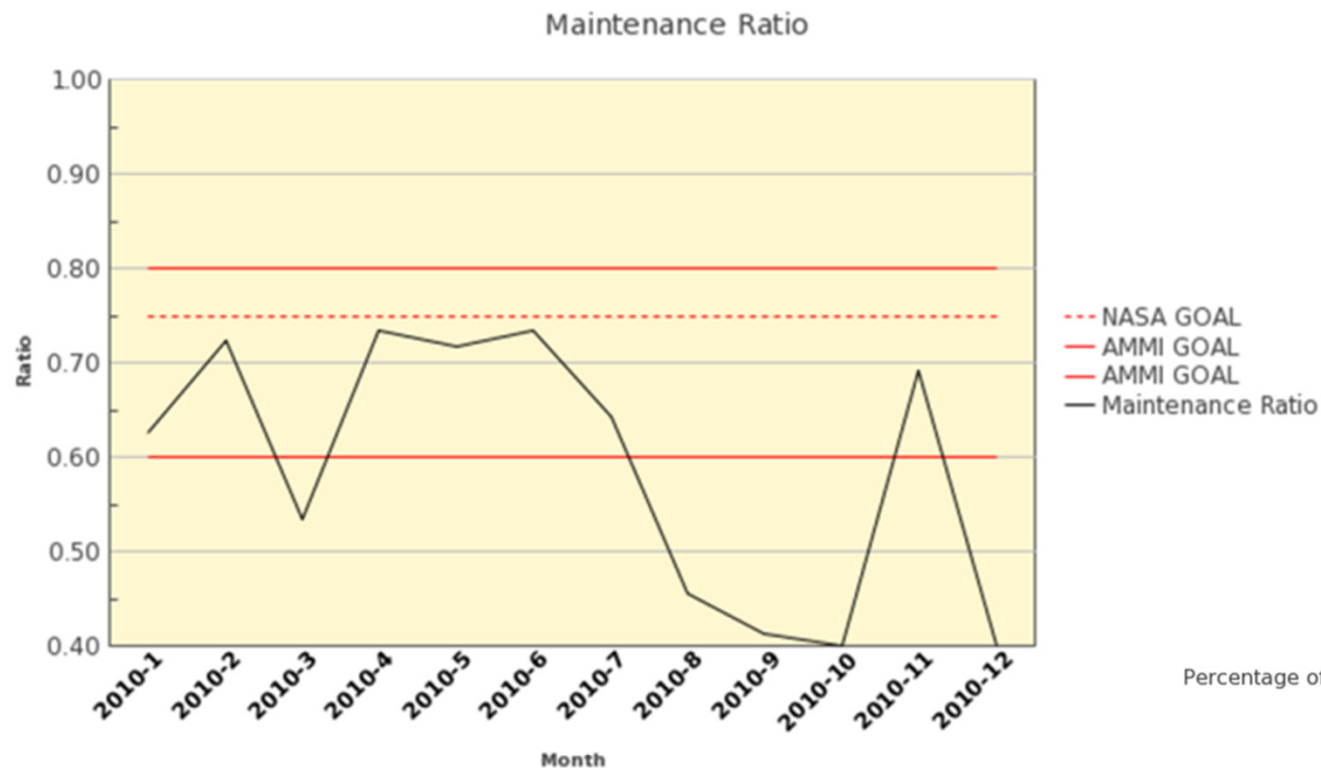
CLU1

GOLDSTONE

DTT



Asset Maintenance

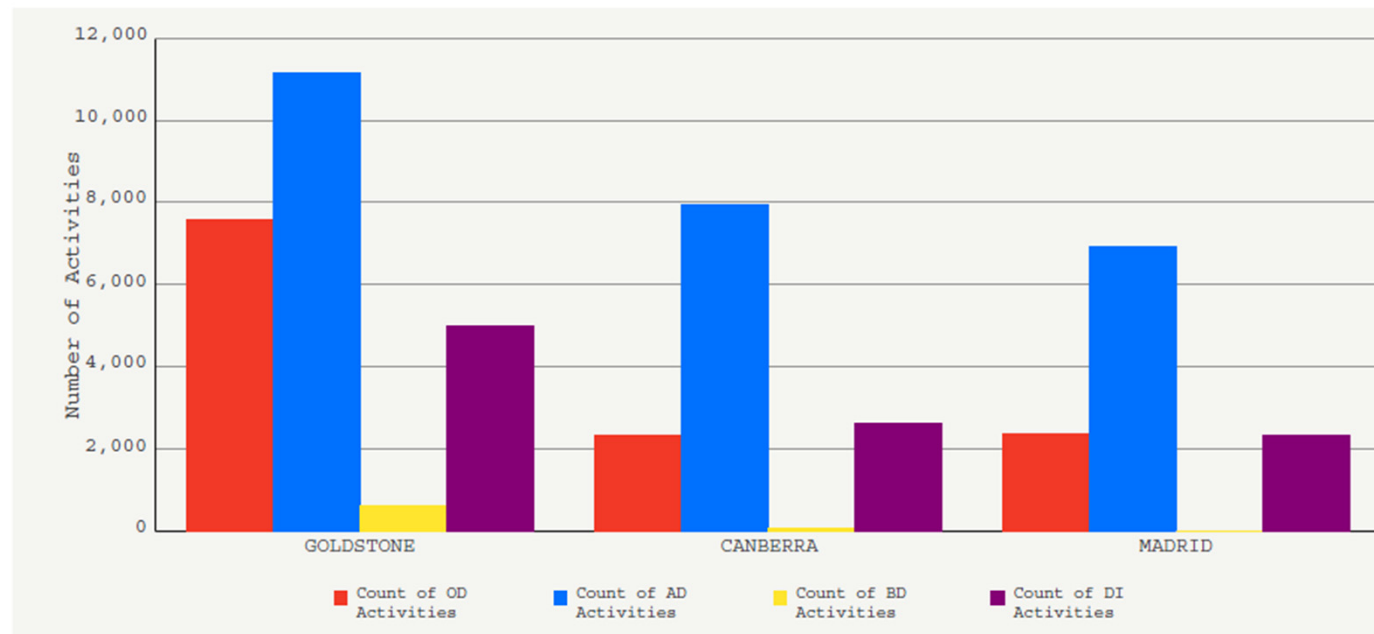




Operator Workload Analysis

Number Of OD AD BD DI Activities, by DSCC, for Last Week

2010-44 -- Week starting DoY 305 44 2010



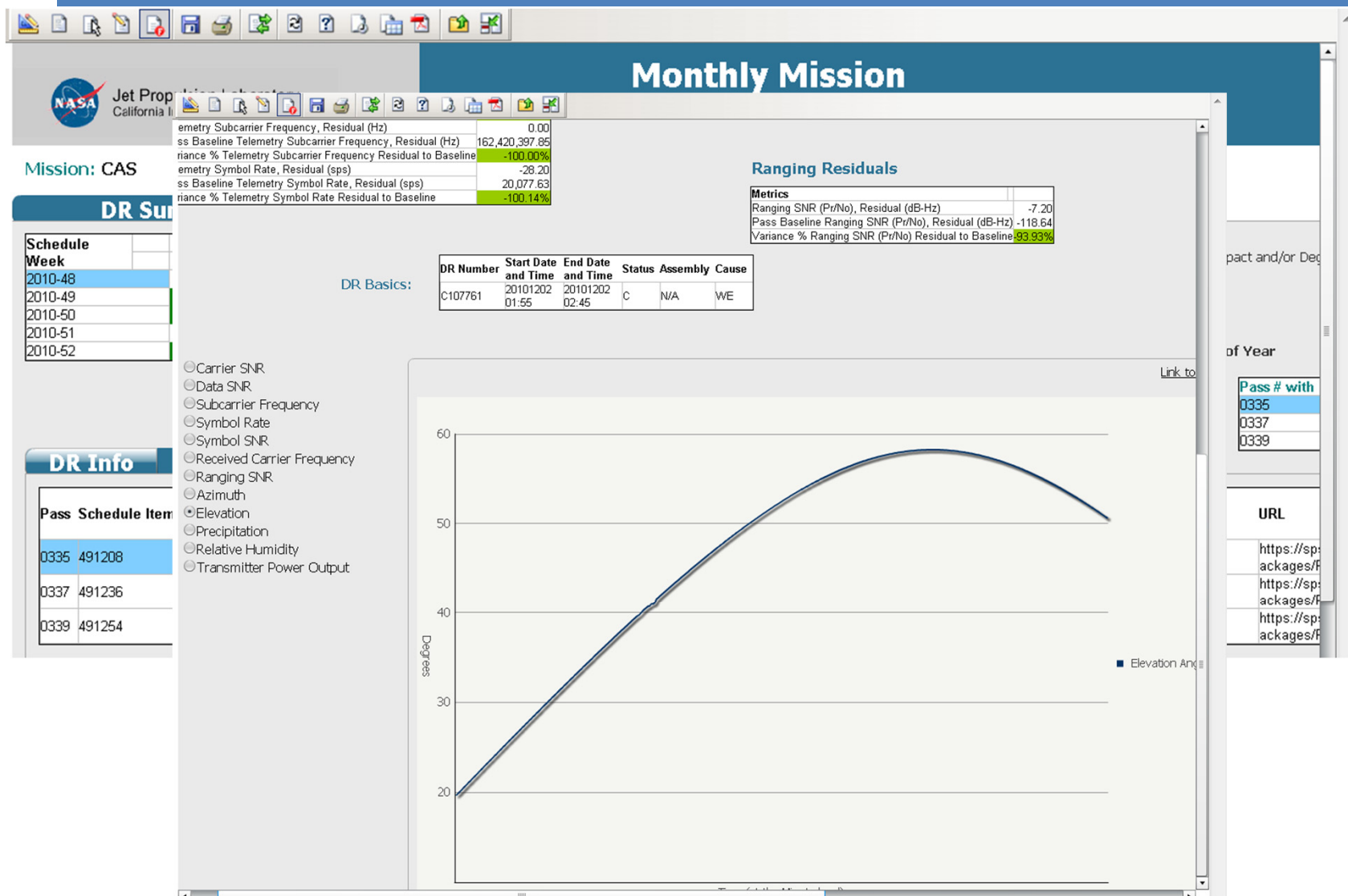
Number Of OD AD BD DI Activities, by DSCC, for Last Week

2010-44 -- Week starting DoY 305 44 2010

DSCC Location	Metrics	Count of BD Activities	Count of AD Activities	Count of DI Activities	Count of OD Activities
GOLDSTONE		626	11,164	4,968	7,608
CANBERRA		65	7,963	2,640	2,312
MADRID			6,934	2,345	2,352

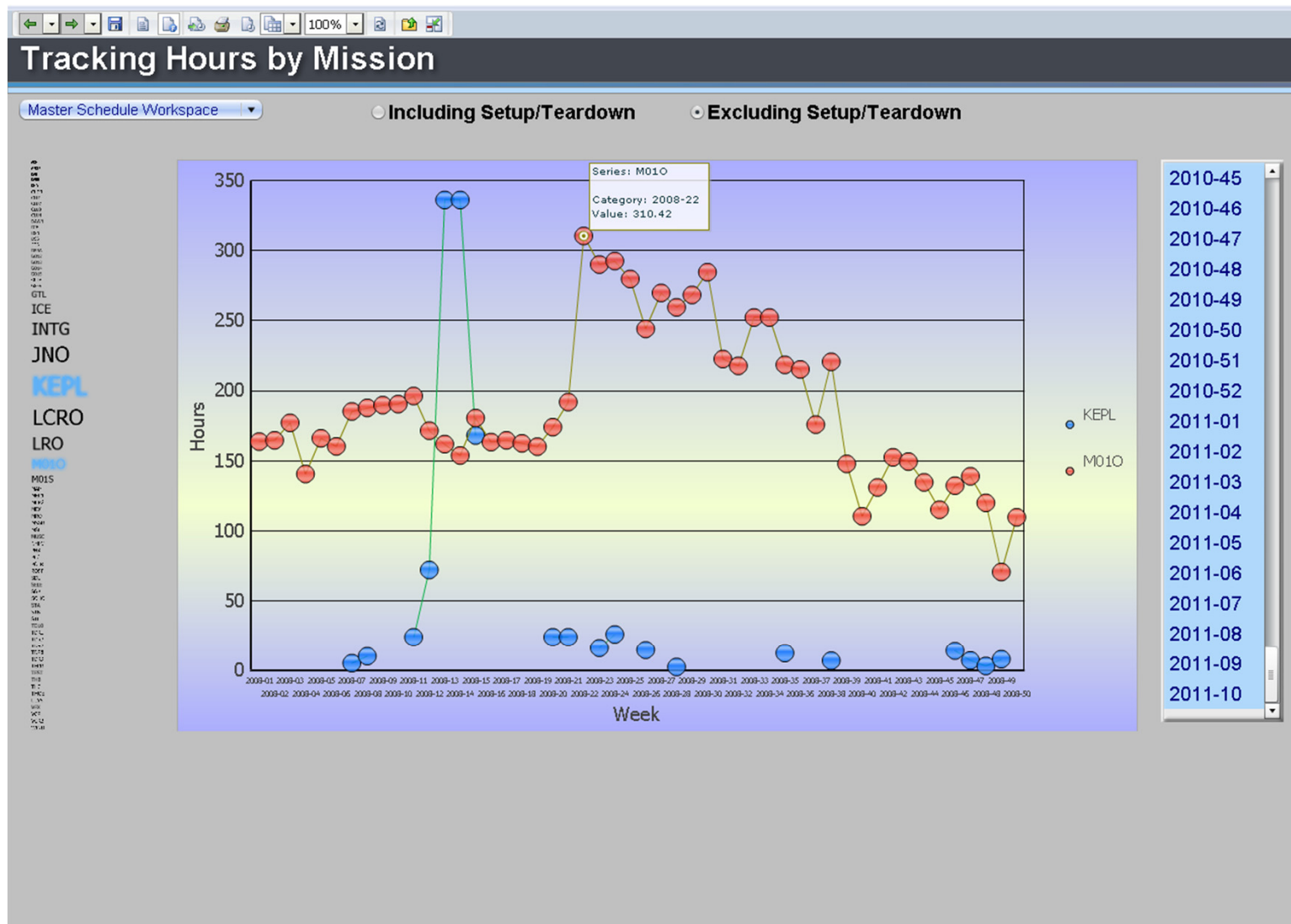


Subsystem Performance



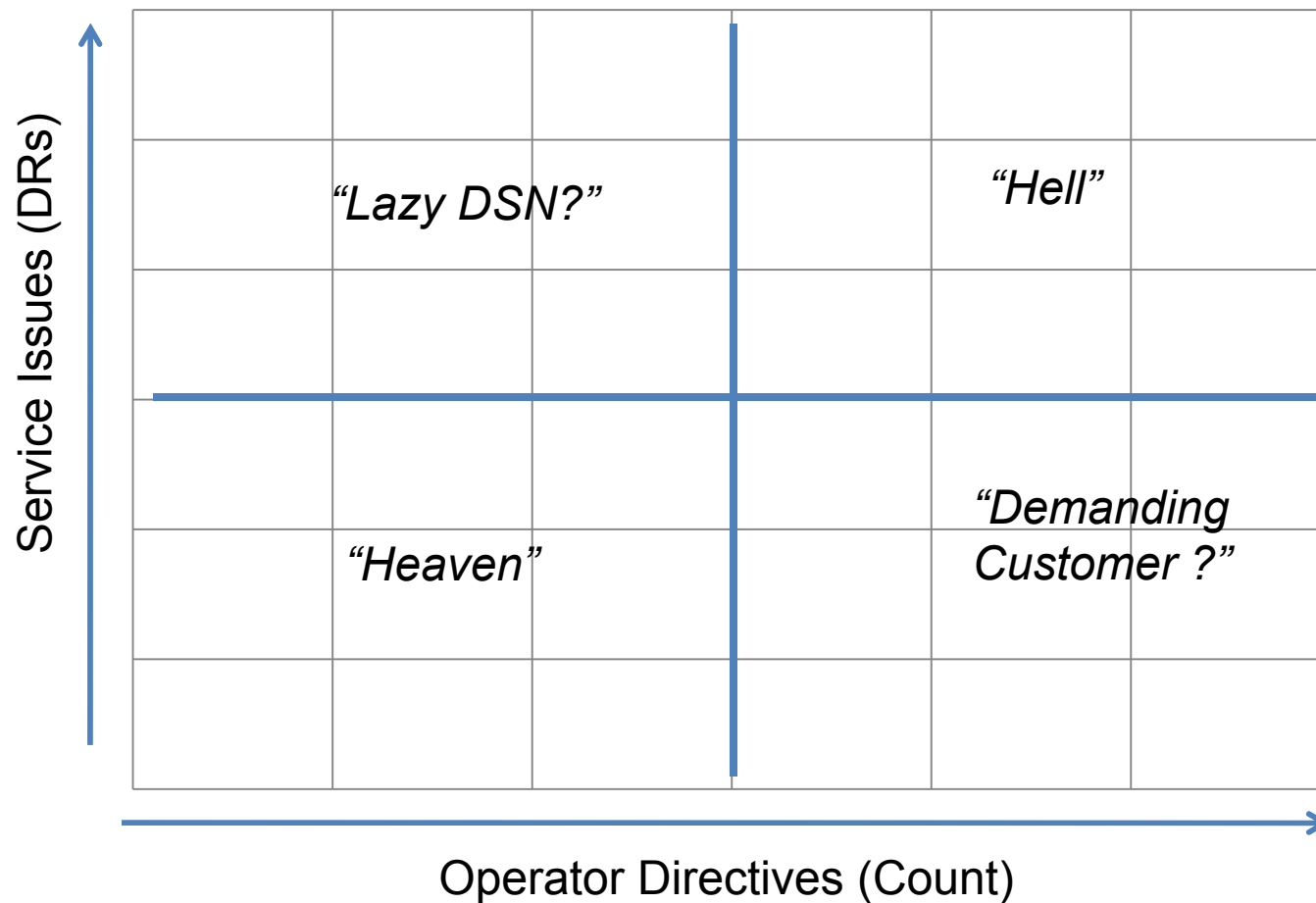


Asset Allocation



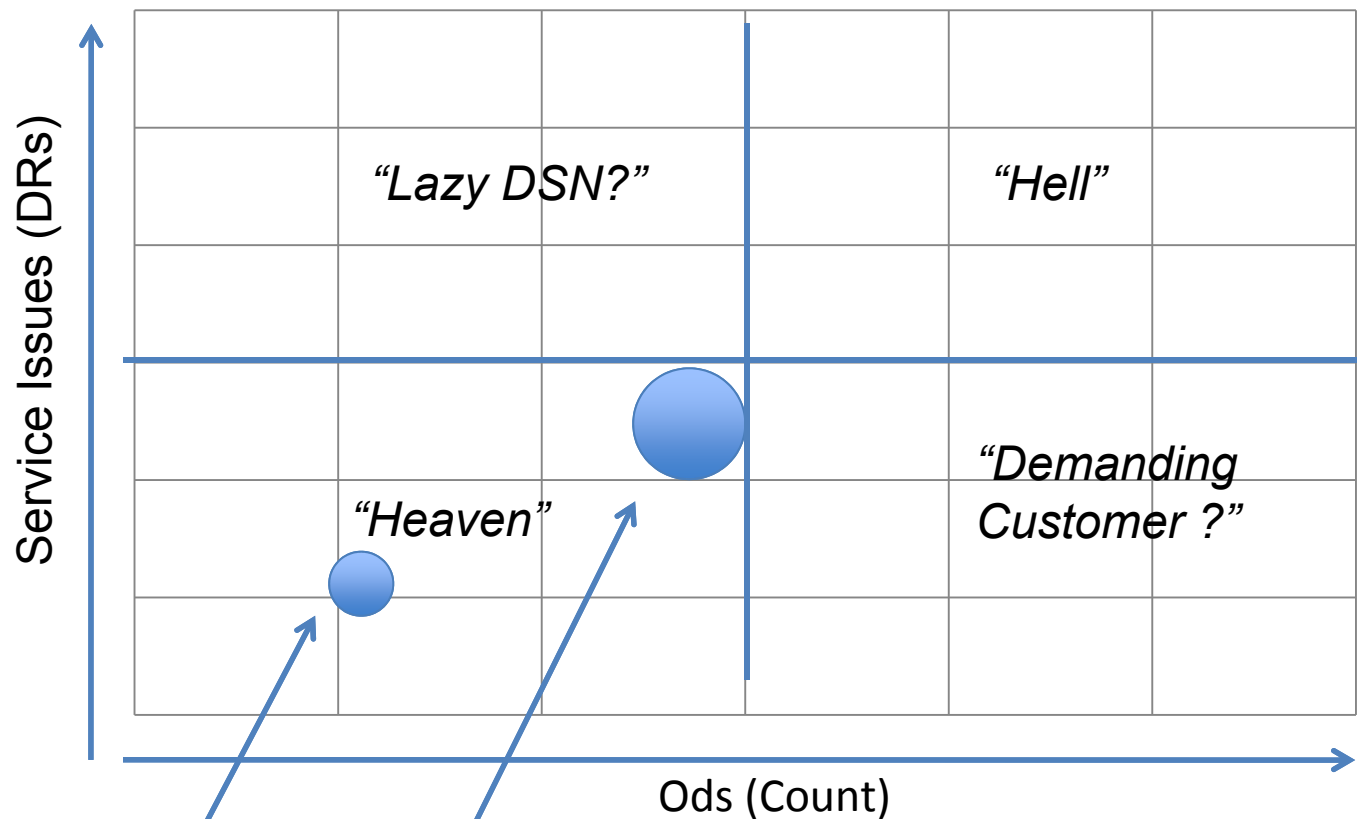


Characterizing DSN Service Delivery





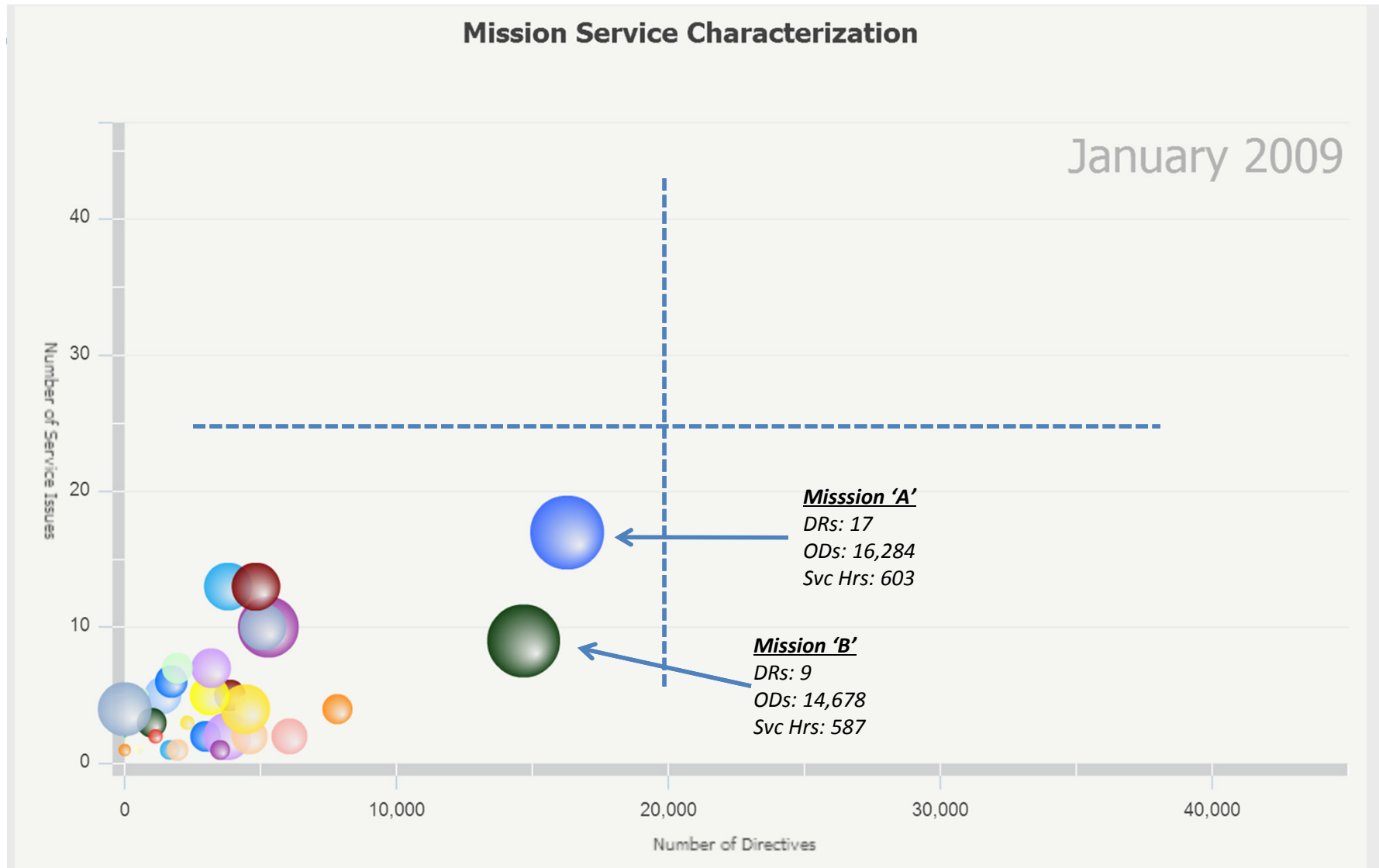
Characterizing DSN Service Delivery



Volume of DSN Services Received: More service → bigger bubble (Hrs)



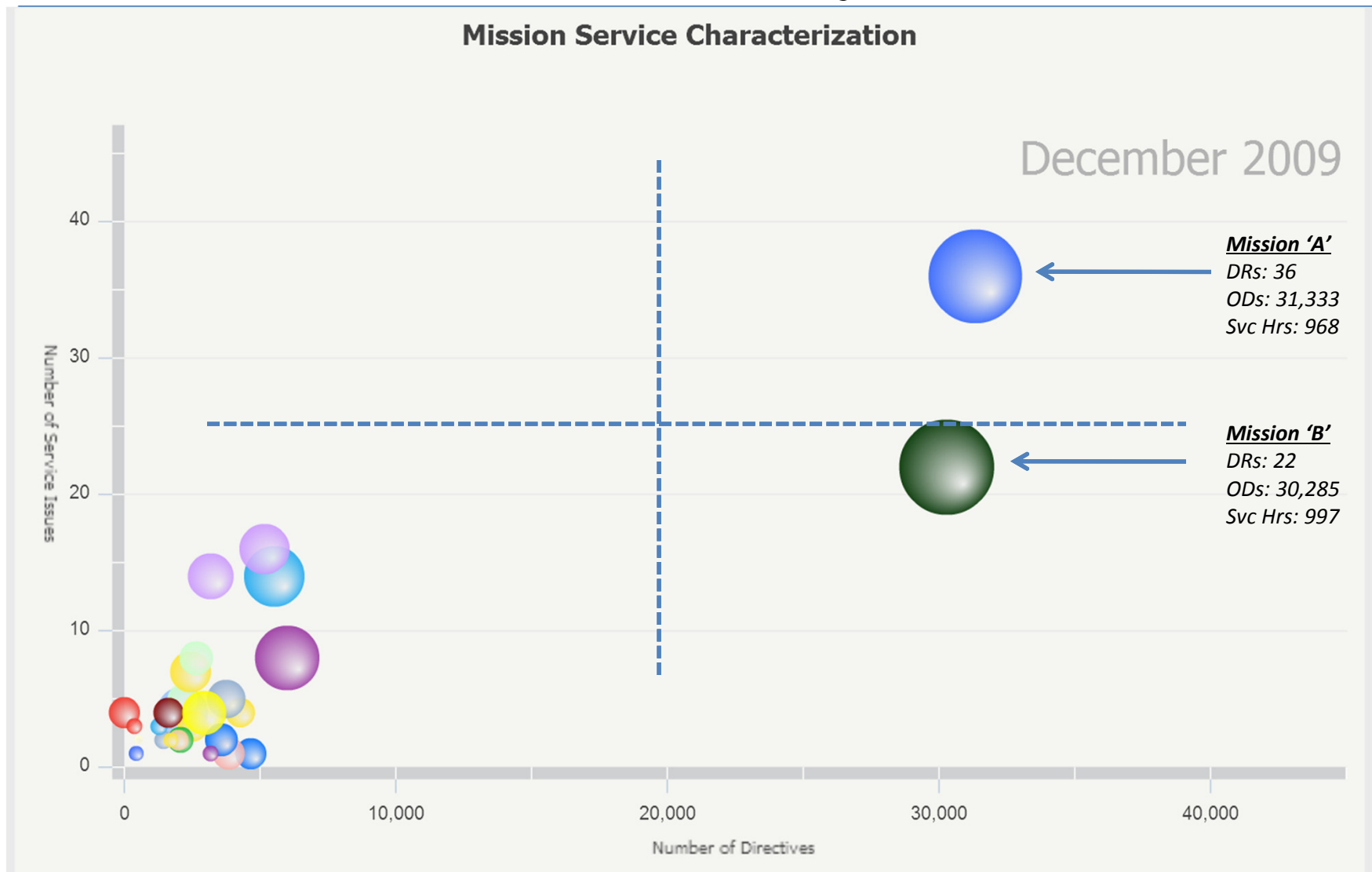
Example Application: A Heavenly Month*



*Data on this and next two slides drawn from in-development effort ; data has not been verified; Mission names have been altered.



Example Application: A Not So Heavenly Month





The Two Year Lazy/Heaven/Demanding/Hell View...



Animated Chart



Lessons Learned

- Don't bypass the semantic and logical data modeling design process. Short-term gains can result in long-term pains
- 80% of effort is in the ETL. Be patient to get to the fun part
- Integrate ETL job status into automated report publishing
 - Clean and validated data is critical (but dirty data tells a story as well!)
- Design for interactive analysis. BI. is more than periodically publishing standard reports
- Think full life-cycle. Maintainability is a key factor in operational costs
- Start with use cases and associated workflows when designing logical and physical data model and when defining application objects
- Don't oversell "ad-hoc" reporting. Sandboxes are practical.
- Enlist domain experts as part of the BI team



To Summarize...

- We have had some good successes
 - Automated report generation for management
 - Decision support re operational application of automation software
 - Some very interesting insights re volumes of service and service quality
- We underestimated the degree in deriving KPI for non-traditional application
 - Still working on this
 - Answering questions breeds more questions
- We look forward to further building our BI capability
 - Data mining/machine learning applications
 - Complex Event Processing + BI in support of better service automation



Thank You For Your Time + Attention

Questions?

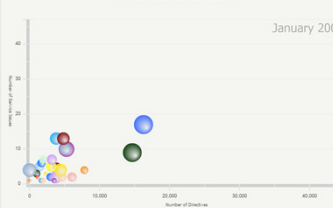
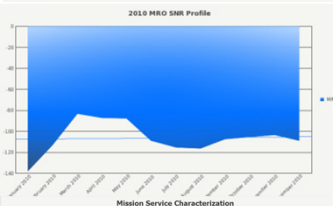
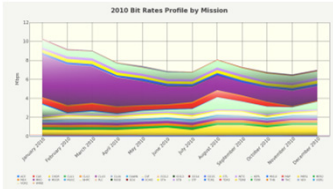


Table showing Mission Service Characterization data for January 2009. The table is organized into columns for Mission, DCCC, Subsystem, Assembly, and Cause. The data is presented in a grid format with red and white cells, indicating different states or values for each mission and subsystem.

